Effects of Dominance and Laterality on Iris Recognition

Amanda Sgroi, Kevin W. Bowyer, Patrick Flynn
University of Notre Dame
Department of Computer Science and Engineering
Notre Dame, IN 46556
asgroi,kwb,flynn@nd.edu

Abstract

Eye dominance, the tendency to prefer to process visual input from one eye over the other, is a little discussed topic in iris biometrics. It has been seen in experiments that one eye tends to have improved performance over the other. One possible cause of this variation in performance could be the distribution of eye dominance among the subject population. In this paper we explore the effects of eye dominance on iris recognition. We also show how eye dominance can be used to guide the development of a single-eye recognition system. An exploration of the correlation between eyedness and handedness is also presented.

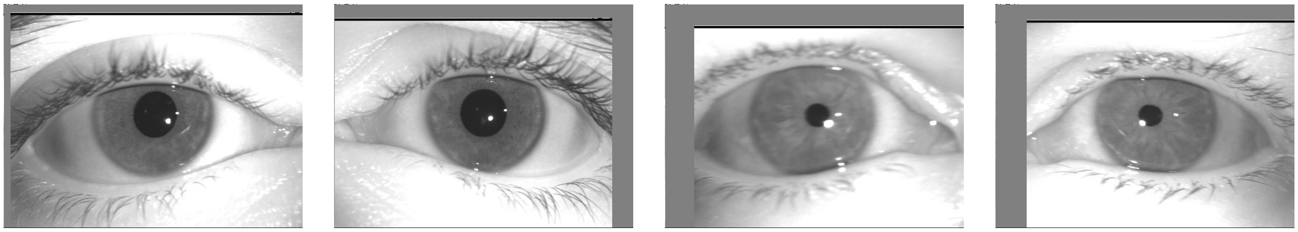
1. Introduction

Eye or ocular dominance, often referred to as eyedness, is the tendency to prefer to process visual input from one eye (the dominant eye) over the other. It has been seen that about 67% of the population is right eye dominant, leaving the remaining 33% of people left eye dominant [9][4][23]. The effect and relationship of eyedness to other dominant features of a person such as handedness is a frequently discussed topic in the psychology and medical fields. This relationship between dominant features is typically associated with the concept of laterality, the preference to use one side of the body. In pyschology, eye dominance and laterality are examined for use in disorder diagnosis as well as in the study of child development [19][4]. Neuroscientists use studies in this area to explore imbalances in the brain for diagnosis of particular diseases[30]. Sports scientists have explored the effects of eye dominance in golf, shooting, and other eye hand coordination activities [2][28][17]. However, no one has explored the impact of eye dominance or laterality yet on iris biometric performance. It is at least plausible that eye dominance could effect performance of iris biometrics, for example through the ease of a user presenting one eye or the other for imaging.

Throughout the last century, many psychologists have explored the phenomenon of eye dominance. The first noted work on eye dominance was in 1593 by Porta [25]. In 1928, Miles established the basis for how eye dominance is determined today [14][15][13]. Several other methods involving either single eye focus or fixation have been developed and explored since then [26][23][29][16]. Eye dominance determination has been used in several studies. Banister used eye dominance to explore rifle usage and then expanded it to assess soldierliness [2]. Yet, in the 1970's psychologists began to focus on determining the relationship between eyedness and handedness. In particular, Coren and Porac published a multiple papers exploring the topic in different setting with various populations[6][7][23][24]. The strength of the relationship between eyedness and handedness is still debatable, and many conclude that the correlation is only slightly better than chance [22][5][8]. Yet, it is agreed that childhood pressures to be right handed in many cultures often oppose the body's natural disposition to laterality, and this may be a cause of the discrepancy.

In iris biometrics, right and left eye are often considered together in an iris recognition system. However, when right and left eyes are considered separately, a variation in performance is sometimes seen. For instance, in the ICE 2005 report a verification rate of 0.995 at a false accept rate of 0.001 was reported for right eyes [20]. In contrast, left eyes only showed a verification rate between 0.990 and 0.995 at the false accept rate of 0.001. When new comparisons were presented in the ICE 2006 and the IRIS 2006 reports, the same relative performance for both and left and right eyes was exhibited [21][1].

Many iris sensors are built to acquire both eyes of a subject at approximately the same time, ignoring the possible effects of eye dominance or laterality. In a technical publication regarding the usage of a single eye sensor however, a phenomenon regarding subjects' eye dominance was reported [3]. During the enrollment process subjects typically presented their dominant eye first and were easily enrolled. But when they then presented their nondominant eye, many subjects had difficulty aligning that eye for proper enroll-



(a) (b) (c) (d)

Figure 1. Images of irises taken by the LG 4000 during the same session. (a) Right eye image from Right Eye Dominant Subject. (b) Left eye image from Right Eye Dominant Subject. (c) Right eye image from Left Eye Dominant Subject. (d) Left eye image from Left Eye Dominant Subject.

ment. To overcome this challenge, many had to cover their dominant eye and attempt to be reacquired. This effect begs the question of how eye dominance affects enrollment in dual eye systems.

In this paper, we will explore the effect of eye dominance and laterality on the performance of an iris recognition system. Section II discusses the dataset and our approach for determination of eye dominance. Section III presents initial results as well as explores the possibilities of single eye systems using the eye dominance results. The relationship between eyedness and handedness in terms of iris recognition is then examined in this section. Section V then concludes with general results regarding eye dominance and laterality. Lastly, potential future work involving this topic is discussed in Section VI.

2. Dataset

An LG IrisAccess 4000 system was used to collect all of the iris images used in this work. This sensor captures images of both left and right irises at approximately the same time. Two clusters of near infrared illuminators of varying wavelengths provide both cross and direct illumination for each iris [12]. To acquire, each subject first adjusted a tripod on which the sensor was mounted to their height and then stood 14 inches away with their eyes centered in a mirrored window. Each image produced was 640 pixels by 480 pixels in size. For this experiment, left and right iris data was acquired for 421 subjects of which 231 of the subjects were male and 190 were female. Data was collected over a period of four weeks during September and October of 2011.

For each subject eye dominance was determined by a Miles Test [13]. In the original Miles Test, subjects held a truncated metal cone over their faces while both eyes were open and aimed it at a distant point. One eye at a time was then closed and whichever eye most clearly saw the distant point was recorded as the dominant eye. This test has been transformed in many ways, most popularly through the hole-in-card test. In our study, subjects form a triangle with their hands and focus a poster on a distant wall in the center. They then close one eye at a time and identify the eye through which they saw the most of the poster.

Using a variant of the Miles test, 271 subjects determined themselves to be right eye dominant and 150 reported left eye dominance. Of the right eye dominant subjects 151 of them were male and 120 were female. Within the left eye dominant set 80 subjects were male and 70 were female. Subjects reported eye dominance each week that they had images acquired and no subjects changed their eye dominance between weeks. Thus, for this experiment we are assuming eye dominance does not change over time.

In each experiment described, the VeriEye SDK version 2.3, a product of Neurotechnology, was used to analyze the data [18]. VeriEye is a commercial package which we used for both iris template extraction and matching. No details regarding VeriEyes feature extraction or matching algorithms are publicly available. VeriEye reports an asymmetric similarity score which ranges from 0 to 9433, where 9433 is produced when the gallery and probe images are identical. Asymmetric scoring means that given a pair of images, VeriEye will produce a different match score depending on which image is used as the probe image.

Further, in this work on each ROC cuve presented error bars are shown, which represent 95% confidence intervals calculated via bootstrapping. In particular, match and non-match scores were subsampled according to their score distributions, and an ROC curve was generated for each of 5000 bootstraps and used to create the error bars. If two error bars at a particular FAR do not overlap, then the difference between the two curves at that FAR is statistically significant. However, if the error bars of two curves do overlap, statistical significance cannot be determined without further testing. This method is based upon the technique described by Wu et al [31]. Using these results, a relative ordering of sensor performance can be established by comparing true accept rate at a particular false accept rate.

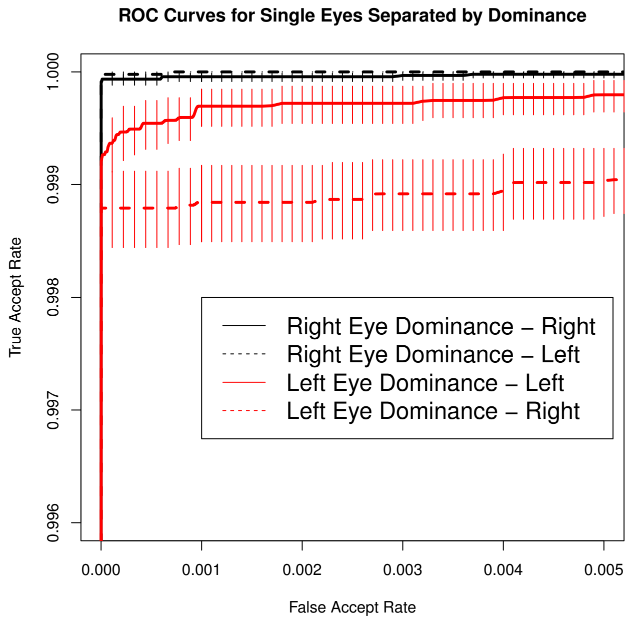


Figure 2. ROC Curves with error bars for the four initial eye dominance experiment. Experiments with right eye dominant data, outperform the experiments employing left eye dominant data.

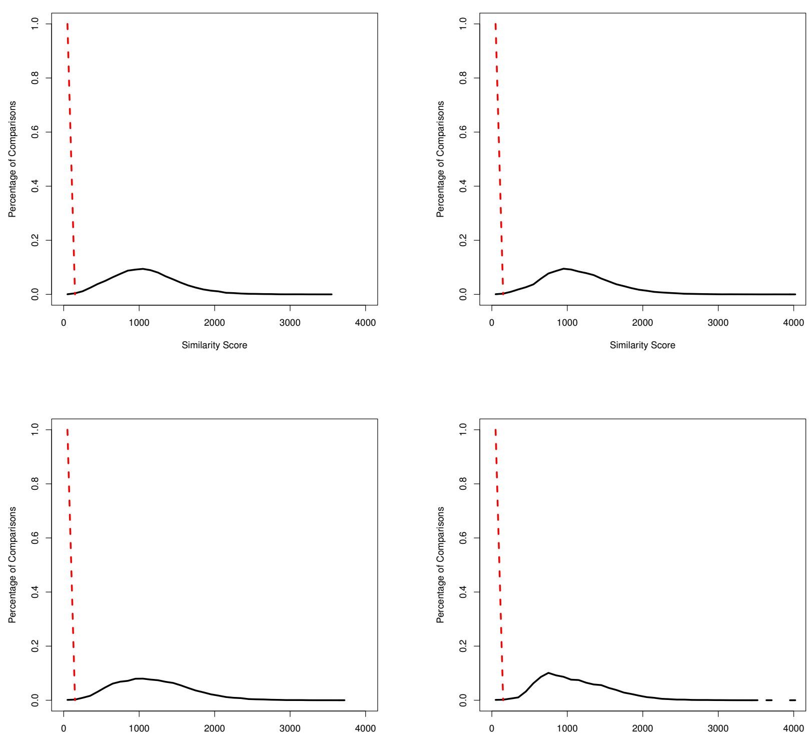


Figure 3. Authentic and Impostor Distributions for the initial eye dominance experiments. The red dashed curve depicts the nonmatch distribution and the black solid curve depicts the match distribution for the Right Eye Dominant Right Eye Experiment (Top Left), Right Eye Dominant Left Eye Experiment (Top Right), Left Eye Dominant Left Eye Experiment (Bottom Left), and Left Eye Dominant Right Eye Experiment (Bottom Right).

Table 1. Gender of Subjects by Eye Dominance

Dominance	Males	Females	Total Subjects
Right Eye Dominant	151	120	171
Left Eye Dominant	80	70	150

Table 2. Number of Match and Nonmatch Comparisons for the Initial Eye Dominance Results

Experiment	Matches	NonMatches
Right Eye Dominance Right Eyes	92,864	20,251,746
Right Eye Dominance Left Eyes	91,252	19,928,848
Left Eye Dominance Right Eyes	39,776	4,439,796
Left Eye Dominance Left Eyes	39,326	4,398,016

3. Results

3.1. Eye Dominance Recognition Results

The initial experiment explored the difference in iris recognition performance between left and right eyes of subjects with a particular eye dominance. The image dataset was then partitioned into four subsets - right eyes of right eye dominant subjects, left eyes of right eye dominant subjects, right eyes of left eye dominant subjects, and left eyes of left eye dominant subjects. Figure 2 shows the results of these experiments and Table 2 contains the match and nonmatch score counts. It is seen that both cases involving right eye dominant subjects outperform both cases of left eye dominance. However, within each dominance some variations are seen. For right eye dominant subjects, it appears that there is no statistically significant difference in performance between eyes since the error bars of both right eye dominant tests overlap along both curves. By contrast, there is a statistically significant difference between the two left eye dominant subsets. Thus, the dominant left eye has an improved recognition rate over the right eyes and the error bars for each experiment do not overlap.

The match score distributions for each experiment provide some insight into why this effect is seen. For the match distributions of the dominant eye, the scores appear more evenly distributed in a Gaussian fashion than those of the nondominant eye. In particular, for right eyes of left eye dominant subjects, the peak in match scores appears closer to the nonmatch distribution and other scores extend out towards 4000. A similar phenomenon is present for the left eyes of right eye dominant subjects.

Hence, when considering eye dominance in an iris recognition system, right eye dominance has an increased performance over left eye dominance data. Further, when looking at left or right eyes only for each dominance type, which eye is used does not make a stastically significant difference for right eye dominance. In contrast, left eyes for left eye dominant subjects exhibit improved performance over their corresponding right eyes.

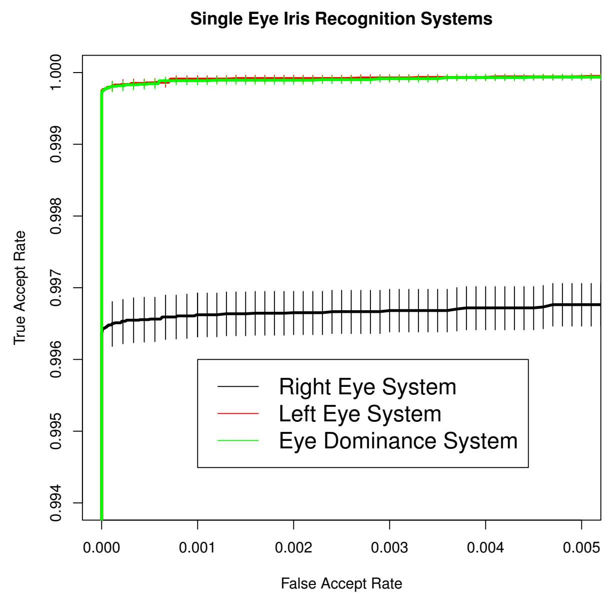


Figure 4. ROC Curves for single eye iris recognition systems. The Left and Right Eye Systems do not consider eye dominance whereas the Eye Dominance System contains only the dominant eye of each subject.

3.2. Single Eye Systems

Given that performance of the right eye dominant subjects regardless of eye used was better than that of the left eye dominant datasets and left eyes of left eye dominant subjects performed better than right eyes, there is an expected outcome for single eye systems. Namely, when using only right eyes or only left eyes, regardless of dominance, left eyes alone should perform better. Figure 4 supports this hypothesis.

To extend this knowledge, we generated a subset of the data to simulate a single eye iris recognition system which considers eye dominance. Namely, a subject would identify their dominant eye and this eye alone would be enrolled. Thus, matches consist of left eye matches from left eye dominant subjects and right eye matches from right eye dominant subjects. Further, nonmatches are derived only from left eye to left eye nonmatches and right eye to right eye nonmatches. By not allowing right to left eye matches we reduce the expense of the system. In Figure 4 we see the comparison of this eye dominance system to left and right eye only systems.

Through the use of the single eye system which considers the eyedness of each subject we have sustained the performance of the left eye only system while including right eye matches. Additionally, we have improved the efficiency and cost of a traditional iris recognition system. Since we only store one eye for each subject we decrease the size of our gallery by half. Further, since we know which eye a subject is enrolling based on dominance, we need only compare to other eyes of that type, decreasing the computational cost of a traditional system.

3.3. Handedness

To further understand the effects of eye dominance, we also explored the notion of how handedness in conjunction with eyedness affects an iris recognition system. Few works in hand based biometrics report or study a person's handedness, and none appear to have looked at the performance rate of a subject's dominant hand in comparison to the non-dominant hand [10][27]. In order to determine handedness, for each subject we viewed videos of them performing various activities such as picking up a telephone, tossing a bean bag, picking up a toy gun, and holding a golf club. This activity based approach of determining handedness is similar to much of the research of determining the accuracy of self reported handedness and correlation to eyedness [2][8]. If subjects performed all activities with the same hand that hand was marked as the dominant hand. Otherwise, that subject was marked as neither right nor left handed and excluded from this experiment. Table 3 shows the subject breakdown given the reported eyedness and determined handedness. This breakdown of handedness is representative of the reported handedness of the world population with about 10% of the population being left handed [11].

Table 3. Subject Breakdown for Eyedness and Handeness

Subject Set	Number of Subjects	Percentage
Right Eyed Right Handed	241	88.93%
Right Eyed Left Handed	13	4.80%
Right Eyed Neither Handed	17	6.27%
Left Eyed Right Handed	116	77.33%
Left Eyed Left Handed	34	22.22%
Left Eyed Neither Handed	0	0%

Figure 5 depicts the results from hand dominance based experiments. Four new subsets of data were formed: right eyes from right eye dominant right handed subjects (87,392 match scores), right eyes from right eye dominant left handed subjects (5,280 match scores), left eyes from left eye dominant left handed subjects (32,870 match scores), and left eyes from left eye dominant right handed subjects (8,124 match scores). Three of the experiments perform nearly perfectly after bootstrapping and are not statistically significantly different. However, left eye dominant right handed left eye results have a degraded and statistically significant performance difference. Since the performance of right eye dominant subjects was already nearly perfect this is not unexpected. However, left laterality outperforms those with left eyedness and right handedness. This suggests the possibility that those who are same side dominant present their eyes better to the sensor than those who are not.

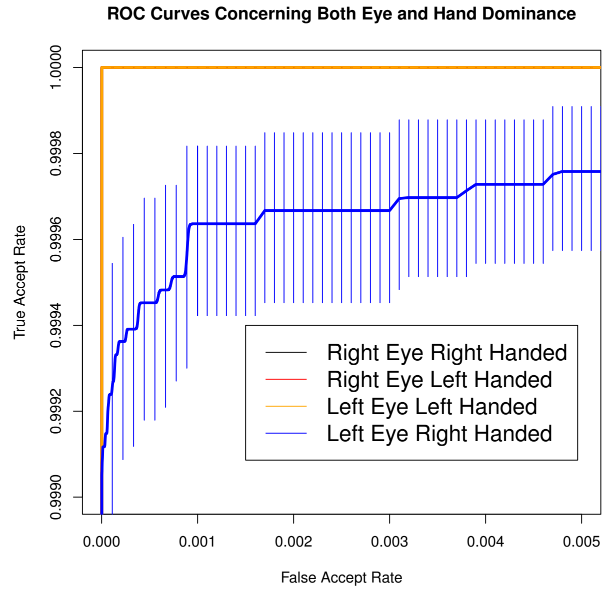


Figure 5. ROC Curves for the correleation between hand and eye dominance experiments. All experiments except Left Eye Dominant Right Handed perform near perfect after bootstrapping.

4. Conclusions

We report on the results of an experimental investigation into the relationship between eyedness, or eye dominance, and handedness and the accuracy of iris recognition. Our results suggest that concepts of laterality, eye dominance and handedness, are correlated with iris biometric recognition performance. This is a novel area of investigation in iris biometrics, and much work remains to be done, but we have obtained interesting and intriguing initial results.

We first subdivided our overall iris image dataset according to the eye dominance of the subjects. We found that for subjects who are right eye dominant, there is not a statistically significant difference in iris recognition accuracy between the left iris and the right iris. However, for subjects who are left eye dominant, we found that iris recognition performance for the left iris was statistically significantly better than for the right iris.

For an iris recognition system that is designed to use one iris, the initial implication is that it is better to base it on the left iris than on the right iris. Alternatively, but more complex, the system could use the dominant eye for each subject. For an iris recognition system that is designed to use both irises, an implication is that the left and right iris results for a left eye dominant subject should be unequally weighted.

We then also considered eye dominance in combination with handedness. We considered the recognition performance of (1) the right iris for right eye dominant and right-handed persons, (2) the right iris for right eye dominant and left-handed persons, (3) the left iris for left eye dominant and left-handed persons, and (4) the left iris for left eye dominant and right-handed persons. We found that recognition performance was essentially the same in 3 of the 4 cases, but that recognition was noticeably poorer for the left iris of subjects who were left eye dominant and right handed.

We conjecture that the results we observe may be due to some difference in how easily subjects with different eye dominance can present the non-dominant eye for imaging. However, the particular mechanism remains to be explained.

5. Future Work

We hope to extend this work in several ways in the future. Initially, we desire to gather a larger dataset and determine eyedness and handedness more accurately. To determine eyedness and remove some of the human error possibly caused by handedness in our current method we plan to employ the hole-in-card method of Miles Testing [13]. In conjunction with subject activity analysis, we plan to ask subjects to self report their handedness. We would also like to more deeply analyze the effects of gender, ethnicity and other covariates which may correlate well with the effects of eye dominance. Further exploration in why these effects occur at all in iris acquisition systems is also planned.

References

[1] Authenti-Corp. Iris recognition study 2006. Technical report, September 2007.

[2] H. Banister. A study in eye dominance. *British Journal of Psychology*, 26(1):32–48, 1935.

[3] F. Bouchier, J. S. Ahrens, and G. Wells. Laboratory evaluation of the iriscan prototype biometric identifier. Technical report, 1996.

[4] D. C. Bourassa, I. C. McManus, and M. P. Bryden. Handedness and eye-dominance: A meta-analysis of their relationship. *Laterality: Asymmetries of Body, Brain, and Cognition*, 1(1):5–34, 1996.

[5] E. R. Brown and P. Taylor. Handedness, footedness, and eyedness. *Perceptual and Motor Skills*, 66(1):183–186, 1988.

[6] S. Coren and C. P. Kaplan. Patterns of ocular dominance. *American Journal of Optometry and Archives of the American Academy of Optometry*, 50:283–292, 1973.

[7] S. Coren and C. Porac. The validity and reliability of self-report items for the measurement of lateral preference. *British Journal of Psychology*, 69:207–211, 1978.

[8] N. B. Cuff. A study of eyedness and handedness. *Journal of Experimental Psychology*, 14(2):164–174, 1931.

[9] I. Eser, D. S. Durrie, F. Schwendeman, and J. E. Stahl. Association between ocular dominance and refraction. *Journal of Refractive Surgery*, 24(7):685–689, 2008.

[10] J. F. et. al. Biosecurid: a multimodel biometric database. *Pattern Analysis and Applications*, 13:235–246, 2010.

[11] C. Hardyck and L. F. Petrinovich. Left-handedness. *Psychological Bulliten*, 84(3):385–404, 1977.

[12] LG Electronics U.S.A., Inc , Iris Technology Division. IrisAccess 4000 : next generation iris recognition system. [online] http://www.irisid.com/download/brochure/IrisID_IrisAccess4000.pdf.

[13] W. R. Miles. Ocular dominance-method and results. *Psychological Bulletin*, 25:155–156, 1928.

[14] W. R. Miles. Ocular dominance demonstrated by unconscious sighting. *Journal of Experimental Psychology*, 12:113–126, 1929.

[15] W. R. Miles. Ocular dominance in human adults. *Journal of General Psychology*, 3:412–429, 1930.

[16] J. Money. Studies on the function of sighting dominance. *Journal of Experimental Psychology*, 24(4):454–464, 1972.

[17] R. Morwood and G. W. Griffiths. Visual performance in cricket. *Optician*, 215(5639), 1998.

[18] Neurotechnology. VeriEye SDK : iris identification for PC and web solutions. [online] http://www.neurotechnology.com/verieye.html, 2011.

[19] S. T. Orton. *Reading, writing and speech problems in children*. Chapman and Hall, London, 1937.

[20] P. J. Phillips, K. W. Bowyer, P. J. Flynn, X. Liu, and W. T. Scruggs. The iris challenge evaluation 2005. *IEEE Second International Conference on Biometrics: Theory, Applications and Systems*, 2008.

[21] P. J. Phillips, W. T. Scruggs, A. J. O'Toole, P. J. Flynn, K. W. Bowyer, C. L. Schott, and M. Sharpe. Frvt 2006 and ice 2006 large-scale results. *NISTIR*, 7408, 2007.

[22] J. S. Pointer. Sighting dominance, handedness, and visual acuity preference: three mutually exclusive modalities? *Ophthalmic and Physiological Optics*, 21(2):117–126, 2001.

[23] C. Porac and S. Coren. Is eye dominance a part of generalized laterality? *Perceptual and Motor Skills*, 40(1):763–769, 1975.

[24] C. Porac and S. Coren. The dominant eye. *Psychological Bulletin*, 83:880–897, 1976.

[25] G. B. D. Porta. *De refractione, optices parte: liber novem*. Horatii Salvania, Naples, 1593.

[26] M. L. Rice, D. A. Leske, C. E. Smestad, and J. M. Holmes. Results of ocular dominance testing depend on assessment method. *Journal of American Association for Pediatric Ophthalmology and Strabismus*, pages 365–369, 2008.

[27] N. C. Sickler and S. J. Elliot. An evaluation of fingerprint image quality across elderly population vis-a-vis an 18-25 year old population. *39th Annual 2005 International Carnahan Conference on Security Technology*, 1:68–73, 2005.

[28] Y. Sugiyama and M. Lee. Relation of eye dominance with performance and subjective ratings in golf putting. *Perceptual and Motor Skills*, 100(3):761–766, 2005.

[29] F. Valle-Inclan, M. J. Blanco, D. Soto, and L. Leiros. A new method to assess eye dominance. *Psicologica: International Journal of Methodology and Experimental Psychology*, 29(1):55–64, 2008.

[30] J. W. VanStrien, G. C. Lagers-VanHaselen, J. M. VanHagen, I. F. DeCoo, M. A. Frens, and J. N. VanDerGeest. Increased prevalances of left-handedness and left-eye sighting dominance in individuals with williams-beuren syndorome. *Journal of Clincal and Experimental Neuropsychology*, 27(8):967–976, 2005.

[31] J. C. Wu, A. Martin, and R. N. Kacker. Measures, uncertainties, and significance test in operational roc analysis. In *Journal of Research of the National Institute of Standards and Technology*, volume 15, pages 517–537. January 2011.